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May 9, 2002

Statement of

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before the

Subcommittee on Space and Aeronautics
Committee on Science
House of Representatives

Mr. Chairman and Members of the Subcommittee:

These are exciting times filled with unprecedented accomplishments in the history of NASA's Earth Science Enterprise (ESE). NASA research satellites' views of Earth from space are providing new perspectives on how Planet Earth works. New observations measure how the Earth is changing, and help us to identify what forces the changes. Substantial uncertainties remain in our understanding of the Earth's climate, and these uncertainties challenge our ability to predict change and make sound decisions based on reliable predictions. NASA's unique and essential contribution to the Nation's global change research endeavor is the global view afforded by the vantage point of space and the scientific expertise to translate these views into useful knowledge. Additionally, NASA finds increasingly broader application in the challenges faced by businesses, agriculture, and local governments across the Nation for these views of Earth.

We are well along in the deployment of the Earth Observing System (EOS) to provide the first holistic view of the major interactions among the Earth's atmosphere, oceans and continents. We achieved another major milestone with the successful launch of the Aqua satellite on May 4th. As its name implies, Aqua will observe Earth's water in all its forms (liquid, solid, and gas) and how it cycles through the Earth's oceans, atmosphere, and land, distributing energy in the form of weather and climate. Working with the National Oceanic and Atmospheric Administration (NOAA), we believe we can use Aqua and other EOS instruments to enable the extension of reliable weather prediction from the current 3-5 days to 7 days by the end of the decade, and improve the overall accuracy of 3-5 day forecasts.

In March we launched the GRACE mission, which will map the Earth's gravity field and its variations with a precision never before accomplished; a precision that will help measure the effect of these variations on Earth's climate. GRACE data will be combined with sea surface topography data from the Jason satellite to enable more precise measurement of sea level changes, and thus assessment of vulnerability of coastal regions to such changes. We are operating and distributing data from the EOS missions already in orbit with the EOS Data and Information System (EOSDIS). EOSDIS delivered over 11 million data products in response to 2.3 million distinct user requests in FY 2001.

NASA is using daily global observations of winds over the oceans by NASA's QuikSCAT satellite to improve marine weather forecasts. The improved NOAA forecasts will predict the onset of storms and hurricanes up to 42 hours in advance over both the Atlantic and Pacific Oceans. The first globally-consistent, 30-meter resolution data set based on Landsat imagery is nearly complete, allowing global assessments of land cover change and its impact on the cycling of carbon through the Earth system. In addition, global radar topography data from the Shuttle Radar Topography missions (SRTM) will improve the imaging of the land surface from 2-dimensions to 3-dimensions, with direct applications to national security, natural hazard assessment and mitigation (e.g., volcanoes and earthquakes), and transportation and water resources management. NASA-sponsored researchers discovered that aerosols (i.e. particles suspended in the atmosphere and that serve as a nucleus for raindrops) can enhance or retard precipitation depending on their origin and type. NASA also provided a series of the first detailed radar maps of Antarctica showing rates of movement of ice from the interior to the oceans. We achieved a 10-fold increase in our capability for computational modeling of Earth's climate system over the best that was available in early 2001, through innovative partnerships with industry. This is a sample of the wealth of new knowledge and unprecedented capabilities streaming from the Nation's investment in NASA's Earth Science Enterprise.

The President's FY 2003 request for Earth Science of $1.628 billion extends this trajectory of success. The budget provides for Major Satellites Development, Research and Technology, Mission Operations, and Mission Support. All the ESE elements are aimed at the goal of answering science questions of societal importance as documented in our *Research Strategy*. This *Research Strategy* was developed through an open dialogue with the Earth science community, and reviewed and endorsed by the NASA Advisory Council (NAC) and the National Academy of Sciences (NAS). The Earth Science FY 2003 budget request will assure public and private sector leaders and citizens have the information they need to make sound decisions affected by climate, weather, and natural hazards.

Earth Science Major Development comprises the development and launch of Earth science satellites, and the development of the EOS data and information system (EOSDIS) to acquire, process and distribute the resultant data and information. The FY 2003 budget request reflects the completion and launch of several EOS satellites, maintenance and operation of EOSDIS, and operation of research satellites that are in Earth orbit. Later this calendar year we will launch the SORCE satellite to understand the influences of solar variability on Earth's climate, and ICEsat to measure changes in the topography and mass of Earth's ice sheets and their role in Earth's

weather and climate. The Aura satellite development will be completed and the satellite will be launched in FY 2004.

NASA is fully committed to extending the key climate data records initiated by EOS through a series of follow-on missions. The Administration is conducting a review of the U.S. Global Change Research Program (USGCRP) and its alignment with the President's Climate Change Research Initiative (CCRI). Consequently, NASA has deferred initiation of any new major EOS missions in FY 2003 until the Administration has completed its review. However, the FY03 budget request includes funds for developing three of our follow-on missions. These include:

- The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), also known as the "Bridge" mission. NPP serves simultaneously to extend essential measurements begun by EOS Terra and Aqua and demonstrate new technology for NPOESS, the converged civilian and military weather satellite system.
- The Landsat Data Continuity Mission (LDCM) as a commercial data purchase. Landsat data are the most widely used in remote sensing imaging agriculture, forestry, and urban and regional planning throughout the U.S. LDCM will ensure the continuity of a vital national resource while marking a significant step in enabling commercial remote sensing capabilities.
- The Ocean Surface Topography Mission (OSTM) to follow the Jason mission launched in 2001. This mission is being implemented in partnership between NASA, NOAA and their European counterparts as a transition mission (along with NPP) between research and operational mission agencies.

The FY2003 budget also provides funding for the study of a potential global precipitation measurement (GPM) satellite to measure rainfall worldwide for both climate research and assessment of impacts of fresh water availability around the world. Decisions on future EOS follow-on missions will be made following the completion of the Administration's review of climate programs.

Exploratory missions that can yield new scientific breakthroughs are a significant component of ESE's program, and align with NASA's strategic mission to promote research and development. Each exploratory satellite project is a one-time mission that delivers conclusive scientific results addressing a focused set of scientific questions. An exploratory mission may focus on a single pioneering measurement that opens a new window on the Earth system behavior. Since its inception in 1992, NASA has received highly innovative proposals in response to Announcements of Opportunities (AO) issued once every two years. We are currently evaluating six proposals in response to the third AO.

The Earth Science Research and Technology budget funds basic research, applications activities, and technology infusion through open solicitations and peer reviewed grants and contracts. The research program funds competitively selected, peer-reviewed proposals from universities, Government labs, and industry, and comprises the intellectual capital to plan and exploit Earth science missions to answer science questions of societal importance. Products planned for FY 2003 include the characterization of global sources of carbon monoxide, and integrated data sets

for the study of sources and sinks of tropospheric aerosols. Both are identified by the National Research Council (NRC) and the National Academy of Sciences (NAS) as important factors in influencing the Earth's climate system. We will also use satellite and in situ observations to develop a high-resolution model of the Pacific Ocean circulation to understand and assess the impact of seasonal and decadal variations in ocean dynamics on Earth's weather and climate.

The Applications and Education programs goal is to expand and accelerate the realization of economic and societal benefits from Earth science, information and technology. NASA has developed a new Applications Strategy to guide our investments over the next ten years to partner with local governments, academia, and the commercial remote sensing industry to demonstrate new applications of remote sensing data and information. Central to this Applications Strategy are partnerships with service provider Federal government agencies such as National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency (FEMA), and US Department of Agriculture (USDA) who define the needs, work with NASA to assimilate Earth science data into decision support systems, and to implement them with various commercial and local partners. For example, a powerful opportunity exists to develop and apply Earth Sciences capabilities to solve aviation challenges. Air travel in the US and worldwide is seriously limited by poor short-term (0-6 hour) weather forecasts, vaguely defined icing and turbulence boundaries, and other weather issues. High resolution sensing and precision forecasting using advanced space-borne systems coupled with smart airplane cockpit displays and control systems, offer breakthrough opportunities for improving the operational efficiency and safety of air travel.

The Earth science education program uses the Earth System Science concept born out of the holistic view of the Earth from space, provided uniquely by NASA, to revolutionize how Earth science is taught and learned in K-12 and college level courses. For example, this program supports 150 graduate students, and thousands of pre- and in-service teachers in more than 8,000 schools nationwide each year, giving rise to the next generation of scientists, engineers, and informed decision makers to power the U.S. economy.

NASA's Earth Science technology infusion program is making possible the next generation of Earth observing satellites to study climate, weather and natural hazards. These will be cheaper and far more capable than today's satellites due to technology investments in new instruments, communication pathways, and spacecraft systems. Our investment in advanced technologies will also help shorten the development cycle of satellites and hence reduce their overall life cycle costs. This budget continues development of Earth Observer-3, leading to the next generation of geostationary weather satellites that will measure atmospheric temperature and humidity for weather and climate research with unprecedented accuracy and resolution. The Earth Science Mission Operations budget supports operation of thirteen satellites, and operation and maintenance of the ground system for command, and control and handling of the resulting data and information. The Ground Network budget supports tracking and data acquisition of seven Earth Science and five Space Science missions by the Polar Ground Network. Sub-orbital radar and telemetry support is provided for Wallops Range customers. The EOSDIS has been serving millions of users by providing data and information from NASA satellites during the past two years. In addition to operating spacecraft the EOSDIS acquires, processes, and distributes data gathered by the EOS missions. We are now demonstrating, for the first time in the history of

civilian remote sensing, formation flying and a constellation of multiple satellites whose collective power is greater than their sum, and act as a super-satellite.

In your letter of invitation to participate in today's hearing, you requested that I address several specific issues in my testimony. Below is information on each of these issues.

Earth Science Results Expected in FY 2003

We will achieve a better understanding of how the Earth's ice, atmosphere, ocean, land, and biosphere interact with each other as we complete the deployment of the first phase of EOS satellites in 2004. ICEsat will allow us to determine the mass balance of the polar ice sheets and their contributions to global sea level change. We will obtain essential data for prediction of future changes in ice volume and sea level, and also acquire the first global measurements of cloud heights and the vertical structure of clouds and aerosols in the atmosphere.

NASA has been working to establish a long-term record of sea ice duration and extent; in FY03 we will complete a record spanning 1979—2000 for use in assessing trends in sea ice and how it affects and is affected by climate change. We will also convert our remote sensing observations of Greenland into estimates of mass change over time and its annual variability. ICEsat will yield baseline elevation changes in both the Greenland and Antarctic ice sheets as a basis to detect future changes. These will help scientists to understand the effect of ice sheet changes on sea level, which in turn contributes to our understanding of the vulnerability of populated coastal regions to natural disasters.

Using data from Terra, and other satellites, we will integrate data from several instruments to generate an assessment of the sources and sinks of aerosols in the lower atmosphere. Aerosol distributions and properties are key sources of uncertainty in projections of climate change; this effort gets at horizontal distribution, while future missions address vertical distribution and aerosol properties. We will also characterize the atmospheric plume from East Asia to improve the assessment of intercontinental transport of pollution.

Using data from Jason and TOPEX Poseidon as well as buoy data from joint NOAA/NASA programs that have given us a decade-long record of sea surface topography and upper ocean temperature, we will develop a high resolution Pacific Ocean model to reveal the mechanisms of the Pacific Decadal Oscellation, much as we did for El Nino over the last decade. We also will use these and related data to ascertain whether measurable changes in the deep ocean have occurred over the last decade.

NASA's Role in the U.S. Global Change Research Program (USGCRP) and the Climate Change Research Initiative (CCRI)

NASA's Earth Observing System (EOS) and the potential follow-on missions are the principal tools for understanding the causes of global changes and their local and regional impacts. As such, EOS and related ESE satellites have been the principal observing tools of the USGCRP.

NASA contributes the largest amount of funds for climate change research that has supported the USGCRP. The Earth Science Enterprise (ESE) *Research Strategy* is based on a prioritized, hierarchical set of science questions, organized by the themes of variability, forcing, response, consequences, and prediction. The objective of this research is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction capability for climate, weather, and natural hazards. This was developed through consultation with the Earth science community nationwide, and reviewed and endorsed by the NASA Advisory Council and the National Academy of Sciences.

In his speech on June 11, 2001, the President expressed interest in reducing key uncertainties in our knowledge of climate science. These were identified by the National Academies of Science in its 2001 report: how much effect natural fluctuations in climate may have had on past warming; how much our climate could change in the future; how fast change will occur; how our actions could impact it; and what constitutes a dangerous level of warming. The ESE *Research Strategy* aligns with these priorities.

Anticipated Impact of Administration Review on EOS Follow-on Missions

On April 1, Office of Science and Technology Policy (OSTP) Director John Marburger and NOAA Administrator Conrad Lautenbacher presented a new climate change research and technology management structure that had been announced by the President in his speech on February 14, 2002. Above the Committee on Climate Change Science and Technology Integration (CCCSTI) is a Climate Change Policy Panel of White House policy councils for program review. Below the CCCSTI is an Inter-Agency Working Group on Climate Change Science and Technology at the Deputy Secretary/Undersecretary level from the CCCSTI agencies. Under the Inter-Agency Working Group, the new structure replaces the Subcommittee on Global Change Research overseeing USGCRP with a new Climate Change Science Program Office (CCSPO) to be headed by Dr. James Mahoney of the Commerce Department (Deputy Administrator of NOAA). The CCSPO held its initial meeting on April 19, and is leading the effort on the Administration's review of the Nation's global change programs. In the next few weeks, the CCSPO will call for a complete inventory of relevant programs for analyzing government research on climate. The inventory will be the starting point for the development of the Climate Change Research Initiative in the FY 2004 budget. NASA participated in this initial meeting and is prepared to support this review and future activities.

NASA is fully committed to extending the key climate data records initiated by EOS through a series of follow-on missions. Three of those missions are in formulation: NPOESS Preparatory Project (NPP) (also known as the "Bridge" mission), Landsat Data Continuity Mission (LCDM), and Ocean Surface Topography Mission (OSTM). Decisions on other future EOS follow-on missions will be made following the completion of the Administration's review of climate programs.

Earth Science Prioritization Process and Science Community Involvement

The Earth Science Enterprise's (ESE) mission is to develop a scientific understanding of the Earth system and its response to natural or human-induced changes to enable improved prediction capability for climate, weather, and natural hazards. The ESE has three basic activities to fulfill this mission: a research program to increase in our knowledge of the Earth system, an applications program to demonstrate practical use of Earth system information to decision-makers in governments, businesses, and elsewhere, and a technology program to enable new or lower cost capabilities for the study of the Earth system in the future. All three programs rely heavily on the science community in prioritizing research, missions, and projects.

Working with the NASA Earth System Science and Applications Advisory Committee, and the broader national Earth science community, ESE developed the *Research Strategy* for the next decade. NASA requested a National Academy of Sciences (NAS) review of the strategy and incorporated the results of this review in the final version published in December 2000. This strategy is based on a prioritized, hierarchical set of science questions that begins with answering the overarching question: ***"How is the Earth changing and what are the consequences for life on Earth?"*** At the next level there are five fundamental questions:

- *How is the global Earth system changing?*
- *What are the primary forcings of the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of change in the Earth system for human civilization?*
- *How well can we predict future changes in the Earth system?*

The concepts of variability, forcing, response, consequences, and prediction provide a framework for research, but each encompasses a wide range of cross-disciplinary science problems that must be articulated through specific research questions. A great number of such questions have been posed by the nation through National Research Council (NRC) and NAS reports, and the work of the science community, particularly over the last decade. The challenge facing ESE is to balance competing demands in the face of limited resources and chart a program that addresses the most important and tractable scientific questions and allows optimal use of NASA's unique capabilities.

Table 1

Science Priority Criteria

Working with its advisory committee and the broader science community, ESE developed prioritization criteria to help select and order specific questions and the programs to be implemented. These criteria address both scientific needs and implementation realities. From a scientific perspective, the following criteria are considered to be in descending order of priority, starting with Scientific Return; from the standpoint of implementation, they are listed in ascending order of priority.

Science Return

Benefit to Society

Mandated Program

Appropriate for NASA

Partnership Opportunity

Technology Readiness

Program Balance

Cost/Budget Context

Implementation Priority Criteria

Based on these criteria, the ESE identified 23 specific research questions and prioritized them within each category (Attachment 1). The application of these criteria allows for prioritization of specific research questions within each category (e.g., variability). There is a logical progression associated with the research program in that knowledge of the underlying variability, forcing, and response processes is necessary to provide unambiguous answers to questions about consequence and prediction (Attachment 2).

These specific research questions identify key parameters for which observations are required and drive the requirements for the five components of the program: basic research and data analysis; systematic measurements; exploratory measurements; operational precursor and technology demonstration missions; data management and distribution; and assessment. Implementation of the priority criteria varies for each of these components. For example, timeliness is a significant driver in implementing systematic missions, but is less significant for exploratory missions. Practical considerations tend to impact the order in which science projects are pursued, and often result in iteration of project selection.

NASA intends to periodically assess its progress on these priorities in consultation with the NRC and its advisory committee. We are currently updating our *Research Strategy*, as part of the Enterprise and Agency strategic planning process.

We are enhancing our dialog with the external science community, and will engage them in the development of the next edition of our *Research Strategy*. For example, an advisory committee member led a Solid Earth Science Working Group (SESWG) comprised of science community experts, who we chartered to develop a geophysics and geology focused research strategy for the next 25 years. The SESWG drafted a report and set of recommendations for near-term, mid-term, and long-term steps, and presented it in a town hall meeting open to all American

Geophysical Union members in Spring 2001. The working group's report is nearly complete. We have also initiated such science community working groups for carbon cycle and water cycle research. The next step is to ask for an independent assessment of these plans by the NAS. These activities will be included in the inventory NASA is preparing as input to the Administration's review of global change programs.

We believe that an on-going, periodic assessment is a better approach due to the fast pace in research and development in Earth sciences, and the scientific assessments required to support economic policy and decisions. For example, the NRC's 1999 report "Global Environmental Change: Research Pathways for the Next Decade" identified research questions for a broad range of global change research themes, but did not prioritize among them.

NASA's Plans for Enhancing Applications and Access to Earth Science Data

Consistent with the ESE mission, the Applications Program aims to: ***Expand and accelerate the realization of societal and economic benefits from Earth science, information, and technology***. The overarching goal for the Applications Program is ***to bridge the gap between Earth system science research results and the adoption of data and prediction capabilities for reliable and sustained use in decision support***. The program planning strategy for accomplishing this goal focuses on identifying and selecting the highest priority national needs and opportunities. Implementing the Applications Program mission and realizing societal and economic benefits requires NASA and its partners to focus on solutions that are citizen-centered, results-oriented and market-driven.

In consultation with its advisory committee, ESE identifies candidate applications projects using a systems-level "roadmap" showing relationships among Earth system science, remote sensing activities and related technologies being conducted by ESE and other organizations, potential applications, and desired outcomes and expected impacts. NASA management works with objective third parties to conduct independent assessments of candidate applications using pre-established guidelines and metrics. Using this methodology, ESE has identified the following twelve candidate national applications for the next decade and key federal partners:

- Enhanced weather prediction **for energy forecasting** – Department of Energy (DOE) and Environmental Protection Agency (EPA)
- Weather and climate prediction for **agricultural competitiveness** – U.S. Department of Agriculture (USDA) and DOE
- Carbon sequestration assessment for **carbon management** – USDA and DOE
- Digital atmosphere and terrain for **aviation safety** – Department of Transportation (DOT) and the Federal Aviation Administration (FAA)
- Early warning systems for air and water quality for **homeland security** – Office of Homeland Security (OHS), National Imagery Mapping Agency (NIMA), and U.S. Geological Survey (USGS)
- Integrated hurricane and flooding prediction for community **disaster preparedness** – Federal Emergency Management Administration (FEMA) and National Oceanographic and Atmospheric Administration (NOAA)

- Early warning systems for vector-borne infectious diseases for **public health** – National Institutes of Health (NIH), and the Centers for Disease Control and Prevention (CDC)
- Environmental indicators for **coastal ecosystem management** – NOAA
- Environmental models for biological **invasive species management** – USGS, USDA
- Water cycle science for **water management and conservation** – EPA, USDA
- Environmental indicators for "smart growth" for **infrastructure** – DOT, EPA
- Monitoring and prediction systems for **air quality management** - EPA

ESE employs a prioritization process for its Applications Program, as described on our recently published Applications Strategy, analogous to the prioritization process in the *Research Strategy*. While the Applications prioritization criteria are appropriately different from those in *the Research Strategy*, they serve the same purpose.

ESE evaluates candidate applications projects based on the criteria in Table 2. Reviews of candidate applications conform to the schedule associated with the Federal budget process in terms of preparing plans for out-year activities. Table 2 shows the criteria for prioritizing candidate applications. NASA uses priority criteria in descending order to decide which applications to include in the investment portfolio for each fiscal year budget, based on funding availability. NASA applies the same criteria (in reverse order, starting with Cost/Budget Context) to evaluate the capacity for the Applications Program to research and demonstrate the prioritized applications.

Table 2

Applications Priority Criteria

Socio-economic Value

Application Feasibility

Response to Oversight

Appropriate for NASA

Partnership Opportunity

S & T Readiness

Program Balance

Cost/Budget Context

Implementation Priority Criteria

The ESE will work with its partners to establish the steps necessary to demonstrate the application's viability for operational use by a partnering organization. This stage identifies the appropriate approaches and organizations to fill technical and/or business gaps. NASA develops requirements to fill these gaps and issues solicitations that provide opportunities for the public, academic, and private sector communities to contribute solutions. NASA then reviews project proposals using the same priority criteria described above.

The ESE is making significant progress in enhancing applications of NASA Earth science data. For example, NASA has provided recovery support to disasters associated with the World Trade Center, Hurricane Andrew, Montana wildfires, Hawaiian tsunamis, the Mount Etna volcano erupting, lost aircraft in Montana and California, floods on the Mississippi River, and numerous other events. Terra MODIS, QuikScat, Landsat, and SeaWiFS are assisting in monitoring and managing wildfires by providing information on combustion potential, plume dispersion,

weather and climate prediction. Our partners at the University of Maryland, the U.S. Forest Service, and the National Interagency Fire Center, are able to produce fire images within minutes of a Terra overpass. These products can lead to applications in damage and threat assessments and determination of secondary impacts. Other Terra products could be used to help rehabilitate burned areas and identify critical wildlife habitat affected by the fire.

NASA and NOAA researchers have recently shown that remotely sensed wind speed and direction from QuikSCAT can help detect tropical depressions and hurricanes up to 46 hours earlier than current methods. Hurricane cloud monitoring and wind profile and prediction products from Quick Scatterometer (QuikSCAT), Special Sensor Microwave/Imager (SSM/I), Topex/Poseidon, SRTM, Landsat, Atmospheric Laboratory for Applications and Science (ATLAS), Airborne Visible and Imaging Spectrometer (AVIRIS), Sea-viewing Wide Field-of-View Sensor (Sea WIFS) could help predict candidate locations for hurricane landfall and surge, and provide assessments of damage and secondary impacts.

NASA and the Federal Emergency Management Agency (FEMA) are partnering on cooperative efforts to assure alignment of NASA's Natural Hazards research and applications development activities with the operational requirements of emergency management practitioners and agencies, and to facilitate the adoption of resulting science and space technologies by FEMA and other disaster managers. NASA and the Army Corps of Engineers, NOAA, USGS, and a number of universities and private companies, are working together using data from state-of-the-art sensors to develop more accurate and efficient maps and hydrologic models of floodplains for Flood Insurance Rate Maps. This effort is part of FEMA's Flood Map Modernization Program, which will upgrade a 100,000 panel flood map inventory by updating flood hazard data and providing digital format maps for all flood-prone areas nationwide.

We're generating geospatial data of unprecedented quality and quantity, and technology, such as data processing and modeling capabilities, to transform the data into information products and to use the data in analysis and prediction tools. We're in the process of drafting a Cooperative Agreement Notice (CAN) that recognizes that the science and other user communities have similar interests and requirements that can best be met by a cooperative approach to addressing basic issues of data access and distribution. This CAN is a mechanism to continue the types of information systems and services begun by the Regional Earth Science Applications Centers (RESACs), the Applications Research Centers (ARCs), Earth Science Information Partners (ESIPs) and the Synergy Program, while emphasizing the need for solutions that exploit the capabilities of the Internet for data delivery, access to information, dynamic updating of databases and educational utility.

NASA will solicit projects through the CAN to help answer the science questions outlined in the Research Strategy. The projects will participate in the continuing improvement of and ready accessibility of an accurate, uninterrupted series of selected geophysical parameters that cover the 40-year record of Earth observations from space. Simultaneously, the CAN will support projects that address applications of national importance and will provide data products and tools for resource management and policy decision support. These projects will unite previously disparate activities and programs under a unified management approach and take full advantage of public and private resources and partnerships to derive maximum benefit for the public good.

We have chosen the name "Conscia" for these projects, which is Latin for knowledge shared among a group. We expect to announce selection of awards by October 2002.

NASA is also developing guidelines to promote the evolution of the ESE network of data systems and service providers over the next decade to ensure the timely delivery of Earth Science information at an affordable cost and to fully engage the community on data management issues, objectives, and solutions. The SEEDS (Strategic Evolution of Earth Science Enterprise Data Systems) activity, currently in formulation, will establish a unifying framework of standards, interfaces, and levels of service to introduce greater flexibility and responsiveness into the standards, processes, and infrastructure used to support the generation of science data products from NASA science missions.

Conclusion

NASA's Earth Science Enterprise is giving the world its first detailed, scientifically accurate look at Planet Earth. We are learning how our home planet works, how it is changing and why, and we are making this knowledge broadly available to other government agencies, business, academia, and citizens to enable them to make sound decisions to enhance our economy and quality of life. We are enabling improved weather prediction, protection of our natural resources, cost-effective and environmentally safe agriculture and construction, and safer communities. NASA's Earth science is leading-edge research that has immediate practical benefit to the Nation. This FY2003 budget request enables NASA to use the view of Earth from space to understand and protect our home planet.

Hierarchy of Science Questions

Overall: ***How is the Earth changing and what are the consequences for life on Earth?***

Variability: ***How is the global Earth system changing?***

- V1. How are global precipitation, evaporation, and the cycling of water changing?
- V2. How is the global ocean circulation varying on interannual, decadal, and longer time scales?
- V3. How are global ecosystems changing?
- V4. How is stratospheric ozone changing, as the abundance of ozone-destroying chemicals decreases and new substitutes increases?
- V5. What changes are occurring in the mass of the Earth's ice cover?
- V6. What are the motions of the Earth and the Earth's interior, and what information can be inferred about Earth's internal processes?

Forcing: ***What are the primary forcings of the Earth system?***

- F1. What trends in atmospheric constituents and solar radiation are driving global climate?
- F2. What changes are occurring in global land cover and land use, and what are their causes?
- F3. How is the Earth's surface being transformed and how can such information be used to predict future changes?

Response: ***How does the Earth system respond to natural and human-induced changes?***

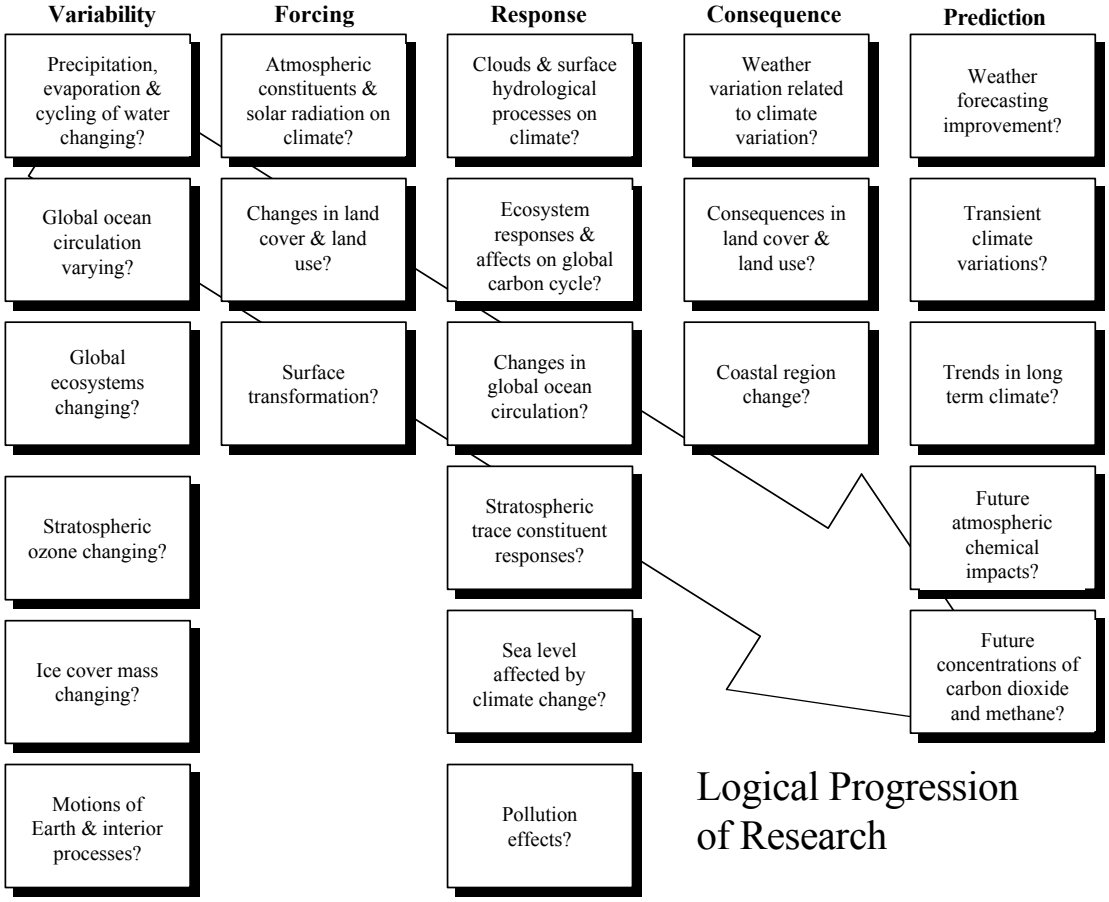
- R1. What are the effects of clouds and surface hydrologic processes on Earth's climate?
- R2. How do ecosystems respond to and affect global environmental change and the carbon cycle?
- R3. How can climate variations induce changes in the global ocean circulation?
- R4. How do stratospheric trace constituents respond to change in climate and atmospheric composition?
- R5. How is global sea level affected by climate change?
- R6. What are the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality?

Consequences: ***What are the consequences of change in the Earth system for human civilization?***

- C1. How are variations in local weather, precipitation and water resources related to global climate variation?
- C2. What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?
- C3. What are the consequences of climate and sea level changes and increased human activities on coastal regions?

Prediction: ***How well can we predict future changes in the Earth system?***

- P1. How can weather forecast duration and reliability be improved by new space-based observations, data assimilation, and modeling?
- P2. How well can transient climate variations be understood and predicted?
- P3. How well can long-term climatic trends be assessed or predicted?
- P4. How well can future atmospheric chemical impacts on ozone and climate be predicted?
- P5. How well can cycling of carbon through the Earth system be modeled, and how reliable are predictions of future atmospheric concentrations of carbon dioxide and methane by these models?


Variability
Forcing
Response
Consequence
Prediction
Precipitation, evaporation & cycling of water changing?
Atmospheric constituents & solar radiation on climate?
Clouds & surface hydrological processes on climate?
Weather variation related to climate variation?
Weather forecasting improvement?
Global ocean circulation varying?
Changes in land cover & land use?
Ecosystem responses & affects on global carbon cycle?
Consequences in land cover & land use?
Transient climate variations?
Global ecosystems changing?
Surface transformation?
Changes in global ocean circulation?
Coastal region change?
Trends in long term climate?
Stratospheric ozone changing?
Stratospheric trace constituent responses?
Future atmospheric chemical impacts?
Ice cover mass changing?
Sea level affected by climate change?
Future concentrations of carbon dioxide and methane?
Motions of Earth & interior processes?
Pollution effects?
Logical Progression of Research